ss, Janney, Elstner Associates, Inc.
ineers, Architects, Materials Scientists

EVALUATION OF CRACKED BRIDGE DECKS TREATED WITH VARIOUS HIGH MOLECULAR WEIGHT METHACRYLATE RESINS

FOR THE

MONTANA DEPARTMENT OF TRANSPORTATION

WJE NO. 981825

July 27, 2000

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Paul D. Krauss, P.E.
Project Manager

MONTANA
PAUL D.
KRAUSS
12654PE
REGISTERED
PROFESSIONAL ENGINEER

WISS, JANNEY, ELSTNER ASSOCIATES, INC.
330 Pfingsten Road
Northbrook, Illinois 60062-2095
847- 272-7400

FAX: 847-291-5189

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INTRODUCTION

Wiss, Janney, Elstner Associates, Inc. (WJE) was requested to perform condition assessments of selected bridge decks that have been repaired using high molecular weight methacrylate (HMWM) resins. The purpose of the investigation was to determine the effectiveness of the HMWM resins to penetrate and bond cracks in bridge decks. The Montana Department of Transportation (MTDOT) has repaired cracks in many bridge decks over the past ten years using different formulations of HMWM. This study was to determine if the early applications are still effective and to determine if the different formulations are performing similarly.

The field inspections consisted of visual inspections and core sampling at crack locations. Visual inspections were performed of the treated deck surfaces. Special attention was given to identify any new cracks that have occurred since the HMWM treatment. Core sampling was performed at selected locations. Laboratory studies included petrographic examination of the cores to determine the crack characteristics and the depth of resin penetration.

BACKGROUND

Cracking in bridge decks may be caused by plastic shrinkage, drying shrinkage, thermal effects, dead or live loads, reactive aggregates, and aggregates damaged by freezing. Many of these cracks do not pose structural problems and do not need to be repaired.

Some cracks endanger the long-term durability of the deck and should be repaired. HMWM resins can be used to fill bridge deck cracks that do not move significantly. Filling the cracks also helps keep chlorides out of the cracks and away from the embedded steel.

In the monomer form (unpolymerized liquid), HMWM resins have two physical properties that make them good crack fillers. They are low-viscosity materials (flow properties similar to diesel fuel), so they flow readily by gravity into even hairline cracks. Penetration into very fine cracks can be better than penetration into large cracks, possibly due to capillary effects and the excellent surface-wetting properties of the HMWM resin.

HMWM monomers also have relatively low volatility, so they won't evaporate before they polymerize. They differ in this respect from methyl methacrylate resins, which are not suitable for crack filling because the monomer is highly volatile.

HMWM monomers are good solvents, enabling them to bond through minor contamination on surfaces. However, workers should remove curing compounds or asphaltic materials from the deck because the monomer will dissolve them and then thicken, reducing its ability to penetrate fine cracks.

Besides being reasonably clean, the cracks must also be dry. Water prevents crack penetration by the monomer and dilutes the resin, resulting in poor polymerization and bond.

Adding a metallic drier and peroxide to the HMWM monomer initiates polymerization. Workers then sweep, squeegee, or spray the resin on the bridge deck at a rate of about 1 gallon per 100 sq ft. The resin flows into cracks and polymerizes, filling and then bonding the cracks. Broadcasting dry sandblast sand into the resin before it hardens improves skid resistance.

HMWM resins should be applied when the deck and air temperatures are between 55 and 90°F. Special formulations are available to help improve curing during cold or hot weather.

Field Surveys

Mr. Paul D. Krauss of WJE performed the bridge inspections between August 16 to 20, 1999. Local contractors provided the lane protection and coring. Twenty-six bridge decks were examined and

cored. Table 1 shows the list of bridges surveyed, bridge location, deck area, and treatment information. The HMWM resins were applied to the various decks between 1991 and 1998. The treatments utilized different HMWM formulations and suppliers. They were applied under a number of different contracts and by different applicators.

The weather during the surveys was generally warm and sunny. Heavy rains had not occurred during the week prior to the survey. A moderately heavy rain occurred overnight and early morning of August 19, 1999, prior to surveying the St. Regis River Bridges.

Typically two to four cores were removed from each deck. A core log showing the approximate core locations and crack type are shown in Appendix A. Cores were generally taken in areas that represent the typical cracking and existing on each structure. The predominate deck cracking on most decks was transverse (Figs. 1 and 4) with some diagonal deck cracks near skewed abutments. On other decks, the predominate deck cracking was longitudinal or map cracking (Fig. 2). Plastic shrinkage-type cracking was rare. Cores were sometimes taken at cold joints between or in deck patches or joint closure placements (Fig. 3).

Appendix B contains the visual survey comments. Generally, the deck underside was first surveyed to identify through-deck cracks that show evidence of recent water leakage or efflorescence.

New cracks, occurring after the resin treatment, could rarely be found on any of the bridges surveyed. The East Missoula-Bonner bridges (Nos. 22-26) were treated in 1998 and had a very heavy layer of resin and sand on the deck surface, essentially hiding any deck cracks. This made coring at the crack locations more difficult. Cracks often had to be located first from the underside of the deck. Cores from these decks would tend to represent the largest cracks occurring in the deck since medium or smaller cracks could not be located under the heavy resin and sand layer.

Bridges 1 and 2 (Hardy Creek-Ulm) were also treated in 1998 but had less resin on the surface and the resin was worn off in the wheel paths. The remaining bridges, treated prior to or in 1996, had little or no evidence of resin on the deck. Traffic and aging caused the resin to first wear off of the wheel paths, then lanes, and then shoulders. Small areas of resin and silica sand were often observed close to barrier curbs or in deep cracks or pockets of some decks. Rapid surface wear of

the resin is typical as the resin degrades, due to ultraviolet exposure, weathering and traffic. This loss is normal and should not adversely affect the resin in the cracks. The original surface texture and skid resistance is also maintained due to the loss of the surface resin.

Bridge 13 (I-90 WB, MilePost 143.651) was flooded with water as shown in Figure 5. The through-deck cracks were monitored and no active leakage was noted. Also, new deck cracks in the top surface were not identified as the deck surface dried.

Examination of Cores

A stereo microscope was used to examine each core. Examinations used fluorescent and long-wave ultraviolet lighting. Table 2 shows the individual core results. Table 3 summarizes the resin penetration results for each bridge and resin type. Both sides of each crack in every core were examined. The minimum and maximum depths of resin bridging were recorded. Resin often penetrated deeper into the crack but did not bridge the crack. The average resin penetration for all samples ranged between about 3 to 10 mm. Many samples had essentially no penetration into the cracks. Typical crack widths ranged from hairline (0.01 mm) to 0.8 mm, and averaged near 0.2 mm. Dirt filled most of the cracks. No correlation between crack width and resin penetration was found. However, the deepest resin penetration was typically achieved in narrow cracks (less than 0.4 mm).

The depth of resin penetration varied by contract section. Poor penetration occurred at I-90 Missoula District bridges (Nos. 15 and 16 – Transpo), I-90 Three Forks bridges (Nos. 6 to 11 – Sika), and I-15 Lincoln Road-Sieben (Nos. 2 and 3 – Harris). Moderate average penetrations occurred at the other six test locations.

Table 4 summarizes the sampling and penetration results sorted by resin manufacturer. Each material had an average maximum penetration of over 14-mm, except for Sika Pronto 19 that averaged only 2.8-mm average maximum penetration.

A comparison of the penetration of high elongation (low modulus) versus low elongation (high modulus) resins was performed. Transpo Sealate T70MX-30 and Castek T70MX-30 were

determined to be high (30 percent) elongation resins. Transpo T70-10, Sika Pronto 19, and Transpo T70-X are assumed to be low (less than 10 percent) elongation resins. The elongation of the resins supplied by Harris Specialty Chemicals and American Concrete Systems is uncertain. Table 5 summarizes the range of resin penetration for the various resins. Figure 6 shows plots of the range of resin penetration for various crack widths. Both high and low elongation resin types had a large range of penetration depths. Figure 7 shows the range of resin penetration versus crack widths for all cores and resins. Generally, penetration was deeper in cracks with widths less than 0.4mm than for cracks with widths of 0.5mm to 1.2mm. No significant difference in the penetration of high versus low elongation resins was seen in this study.

SUMMARY

Seventy cores were removed from 26 different bridges that had been treated with HMWM. Crack widths at 6-mm depth ranged from hairline (0.01 mm) to 0.8 mm. Dirt commonly filled the cracks. The average maximum resin penetration was slightly over 14 mm, except for bridges treated with Sika Pronto 19 (one contract) that had only 2.8 mm average maximum penetration. Each contract and material type had areas of near zero penetration into the cracks. No significant differences in penetration were noted between high and low elongation resins.

Very few samples or bridges had evidence of new cracking after the HMWM treatments. The HMWM treatments appear to have stopped leakage through most through-deck cracks, however, some through-deck cracks continue to leak.

Restraint of drying shrinking and thermal contraction typically causes the cracking noted on most of the bridges. Stresses transfer to the reinforcing after concrete cracking so additional movement of the cracks tends to be minimal. Structural bonding of the cracks by the HMWM resin on the bridges surveyed is unlikely due to the large amount of crack contamination and the lack of deep resin penetration. Protection against chloride deicer ingress into cracks has been achieved in many areas.

Revisions to specifications or training of applicators may improve penetration results. However, dirty, aged cracks are very difficult to penetrate and seal. Other treatments, such as several coats of high-solids silanes, may penetrate the contamination in the cracks better. Silanes do not fill or bond

cracks but makes them hydrophobic to resist deicer ingress. HMWM resins may penetrate and achieve better structural bond to cracks in newly constructed bridges that contain cracks without significant contamination. A combination treatment of silane followed by HMWM may improve the deck protection further.

Surface abrasion and weathering removes the resin HMWM from the surface after 3 to 4 years. The resin in the cracks has not been affected by time. Only a few cracks appear to have moved, resulting in new fractures in or adjacent to the resin. Re-application of resin to the decks after 4 to 5 years is possible and would improve the deck's water tightness. Testing of the effectiveness of resin re-application should be considered at bridges such as I-90 Three Forks (Nos. 6 to 11) or I-90 St. Regis (Nos. 17 to 20) bridges.

TABLE 1 – SURVEY OF BRIDGES

Bridge No.	Route No.	Feature	Mile point	Deck area (sq yd)	Deck area (M2)	Year applied	Resin
Hardy Creek – Ulm (Northbound)							
1	I-15-SB	So. Cascade Int.	254.942	613.3	512.8	1998	Harris Specialty Chemicals CrackSealer ULV
2	I-15-SB	County Rd. Sep.	249.505	567 2	474.3	1998	Harris Specialty Chemicals CrackSealer ULV
Lincoln Road – Sieben							
3	I-15-SB	Sieben Int.	216.482	482	403.0	1996	Harris Specialty Chemicals Watson/Bowman
4	I-15-SB	Gates of Mtn. Int.	209.108	503 1	420.7	1996	Harris Specialty Chemicals Watson/Bowman
Boulder Hill – Helena							
5	I-15-SB	Abandoned BNRR	187.079	980.0	819.4	1996	Transpo Sealate T70 – 10
Three Forks – Manhattan							
6	I-90-EB	Darlington Ditch	279.534	612	511.7	1993	SikaPronto 19
7	I-90-EB	County Rd. Sep.	280.361	549	459.0	1993	SikaPronto 19
8	I-90-EB	Drainage Ditch	280.1	–	–	1993	SikaPronto 19
9	I-90-WB	County Rd. Sep.	280.361	549	459 0	1993	SikaPronto 19
10	I-90-WB	Drainage Ditch	280.1	–	–	1993	SikaPronto 19
11	I-90-WB	Darlington Ditch	279.534	612	511.7	1993	SikaPronto 19
Bearmouth – Drummond							
12	I-90-WB	Clark Fork	148.436	1253.9	1048.4	1994	American Concrete Systems-Polytech Perma Seal
13	I-90-WB	Grade Sep.	143.651	586.9	490.7	1994	American Concrete Systems-Polytech Perma Seal
14	I-90-EB	Clark Fork	148 436	1253.9	1048.4	1994	American Concrete Systems-Polytech Perma Seal
Missoula Dist. – Br. Rehab.							
15	I-90	Rock Creek Over-pass	126.039	996	832.8	1992	Transpo Sealate T – 70MX-30
16	I-90	Clinton Overpass	120.993	1144	956.5	1992	Transpo Sealate T – 70MX-30
St. Regis River Bridges							
17	I-90-WB	St. Regis Riv., County Rd.	23.325	3030.5	2533.9	1991	Transpo T 70 – X
18	I-90-WB	St. Regis Riv., County Rd.	23.063	2161 25	1807.1	1991	Transpo T 70 – X
19	I-90-EB	St. Regis Riv., County Rd.	23.063	2161.25	1807.1	1991	Transpo T 70 – X
20	I-90-EB	St. Regis Riv., County Rd.	23.325	3030.5	2533.9	1991	Transpo T 70 – X
St. Regis – Tarkio							
21	I-90-EB	Clark Fork	49.397	2673.1	2235.1	1994	Transpo Sealate T – 70MX-30
East Missoula – Bonner							
22	I-90-WB	Blackfoot River	110 198	1425.3	1191.7	1998	Transpo Castek T – 70MX-30
23	I-90-WB	MRL Railroad	110.033	1510.1	1262.6	1998	Transpo Castek T – 70MX-30
24	I-90-WB	Clark Fork & County Rd.	109 409	1246.3	1042.1	1998	Transpo Castek T – 70MX-30
25	I-90-WB	Grade Separation	109.224	608.7	509.0	1998	Transpo Castek T – 70MX-30
26	I-90-WB	Clark Fork	108 276	1419.0	1186.5	1998	Transpo Castek T – 70MX-30

TABLE 2 – CORE TEST RESULTS

Bridge No	Core ID.	Core Length (mm)	Minimum crack width @ 6 mm	Maximum crack width @ 6 mm	Minimum Depth Resin (mm)	Maximum Depth Resin (mm)	Rebar Depth (mm)	Comments
1	A	160	0.03	0.04	3	15	71, trace corrosion	Dirty crack
1	B	100	0.33	0.33	2	3	76, trace of corrosion	Very dirty crack
1	C	160	0.03	0.03	2	17	90, 108 uncorroded	Moderate dirty
2	A	149	0.3	0.5	90	90	61, moderate corrosion, 149 (impression)	Crack dirty, clearly filled with yellow, resin
2	B	141	0.001	0.001	0	1	62, 81 uncorroded	Crack not full depth. Crack slightly dirty
2	C	120	0.07	0.07	2	9	73 uncorroded	One major crack, one minor crack, moderate dirty above rebar
3	A	105	0.2	0.3	1	12	35, corroded	Slightly dirty
3	B	112	0.08	0.1	1	12	27, uncorroded does not intersect crack	Very dirty crack, especially in top portion
3	C	125	0.08	0.05		0	67,125 (impression)	Top bar deeply corroded. Crack dirty above rebar
4	A	110	0.1	0.1	0	1	28 trace corrosion, 45	Small branching crack. Very dirty in top section
4	B	115	0.01	0.01	2	10	19, moderate corrosion	Top section of crack is dirty
4	C	125	0.08	0.08		5	None	Crack branches
5	A	92	0.01	0.01	2	20	31, 48,78 uncorroded	Dirty crack
5	B	120	0.1	0.2	20	20	20, corroded, 94	Horizontal separation at ~20 mm above corroded rebar
5	C	112	0.004	0.004	20	25	41	Moderately dirty crack, not full depth, extends to 55-70 mm.
6	A	115	0.4	0.4	7	7	32, uncorroded, crack doesn't intersect rebar	Top section of crack moderate dirty
6	B	105	0.01	0.05	0	0	None	Dirt in top of crack. Crack barely full depth
6	C	121	0.1	0.2	10	10	50, moderate corroded	Slightly dirty
7	A	116	1.2	1.2	1	2	25, moderate corrosion	patch/depth - 60 mm
7	B	124	0.02	0.03	0	0	None	Dirty crack
7	C	125	0.04	0.04	0	2	27, uncorroded	Two intersecting cracks
8	A	105	0.08	0.08	0	7	23, uncorroded crack does not intersect rebar	Crack slightly dirty
8	B	45	0.15	0.15	0	0	30, 47 (impression)	Uncorroded rebar dirty crack
9	A	35	0.08	0.08	0	0	None	Patch, bottom surface of core is very dirty

TABLE 2– CORE TEST RESULTS (Cont'd)

9	B	70	0.1	0.5	5	5	25, corroded	Incipient delam At 30 mm
10	A	120	0.08	0.08	1	2	47, trace corrosion	One major crack and one minor crack
10	B	120	0.04	0.04	2	3	33, trace of corrosion 76 (imprint)	Two intesection crack not full-depth Dirty
11	A	110	0.04	0.04	0	0	38	Crack not full depth Moderately dirty in top section
11	B	125	0.4	0.4	0	2	45 (uncorroded) 116 and 118 (impression)	Moderately dirty in top section
12	A	121	0.1	0.2	2	2	41	Partial incipient spall at 10-15 mm per big flat aggregate
12	B	125	0.1	0.1	3	5	uncorroded	depth
12	C	140	0.01	0.01	1	3	59, uncorroded	Crack does not intersect bar
13	A	115	0.05	0.05	5	25	42, moderate corroded, 58 uncorroded not intersected by crack	Original crack barely full depth Another crack formed, slightly dirty
13	B	120	0.15	0.15	1	2	35, 115, impression slightly corroded	Crack not full depth
13	C	120	0.1	0.1	1	2	41, slightly corroded	3 cracks, Top section of cracks are very dirty
14	A	118	0.02	0.03	44	44	42, 59 both corroded	Slightly dirty
14	B	106	0.01	0.05	0	3	36, corroded, impression bottom	Very dirty above rebar
14	C	121	0.01	0.01	41	41	41, (Uncorroded, not intersected) 57, slightly corroded	Crack slightly dirty
15	A	110	0.1	0.1	1	2	45	Rebar corroding where crack intersects it
15	B	75 to 115	0.02	0.05	0	0	38, 54	Both bars corroded at cracks Moderate dirty cracks
16	A	98	0.04	0.04	0	0	38 rebar corroding at crack	New crack in near-surface zone Crack very dirty
16	B	105		NA-core broke apart in lab	0	0	46, corroded	Moderate drity crack
17	A	157	0.03	0.13	0	10	78,86,157 (impression)	
17	B	159	0.01	0.03	2	90	76, uncorroded	Slightly dirty
17	C	175		NA-core broke apart	1	2	73 moderate corroded, 96, 168 impression	Crack not bonded Horizontal separation at 73 to 105 mm
17	D	162	0.05	0.005	1	2	65, 83 (chair) uncorroded	Dirty crack

TABLE 2– CORE TEST RESULTS (Cont'd)

18	A	75	0 8	0 8	0	1	58, corroded	Crack rec almost separated Very dirty
18	B	160		NA	0	4	57, slightly corroded, 156 impression	Crack not bonded Horizontal separation below rebar at ~125
18	C	150	0 8	0 80	3	9	54, 76 bot rebars corroded	Very dirty crack
19	A	156	0 2	0 2	1	20	62, corroded	Crack in concrete intersects full thickness grout
19	B	160	0 5	0 5		0	66, moderate corrosio	Slightly dirty
19	C	158	0 02	0 03	2	60	61, 81 moderate corrosion	Crack dirty above bar
20	A	160		NA	1	12	None	Separated along key way
20	B	170	0 5	0 5	1	2	75	Crack angles out of plane of core Moderate dirty
21	A	125	0 2	0 2	2	30	47, Corroded, crack interesects rebar	Branching crack
21	B	144	0 03	0 03	1	2	41, moderate corrosion; 145 (impression)	Dirty crack
21	C	122	0 2	0 3	10	20	43, trace corrosion	Dirty
22	A	148	0 02	0 03	1	2	90, epoxy coated	Moderate dirty Resin mixed with dirt 10 to 15 mm
22	B	207	0 1	0 1	4	5	68, green bar uncorroded	Crack not full depth, dirty in top section
22	C	159	0 7	1	12	17	82	Dirty crack
23	A	190	0 03	0 05	0	0	60, 131 epoxy coated, uncorroded	Crack not full depth. Moderate dirty above rebar
23	B	153	0 1	0 3	1	2	73 green bar, uncorroded	Dirty in upper part of crack
23	C	110			5	10	60, 87	Dirty crack
24	A	130	0 4	0 4	0	12	None	Significant unconsolidation along core Dirty cracks
24	B	150	0 3	0 4	3	4	None	Very dirty
24	C	120	0 2	0 4	7	8	87, moderate corrosion	Dirty crack Pea gravel overlay
25	A	165	0 25	0 25	12	30	86, 99, 101, 118 (impression) Part top of rebar corroded where crack intesects it	Crack dirty
25	B	160	0 35	0 4	1	15	106, curved moderate corrosion	Crack moderately dirty
26	A	155	0 2	0 5	35	55	None	Moderate dity
26	B	155	0 2	0 2	25	25	89 uncorroded not intersected by crack	Horizontal separation from at 57 mm to level of rebar

TABLE 3 – SUMMARY OF RESIN PENETRATIONS

Bridge No.	Route No.	Feature	Range of penetration (min/max)	Average minimum depth of bridging (mm)	Average maximum depth of bridging (mm)	Section average minimum depth (mm)	Section average maximum depth (mm)
Hardy Creek – Ulm (Northbound) Harris Specialty Chemical, Crack Sealer ULV							
1	I-15-SB	So. Cascade Int.	2-17	2.3	11.7		
2	I-15-SB	County Rd. Sep.	0-90	30.6	33.3	16.4	22.5
Lincoln Road – Sieben Harris Specialty Chemicals, Watson/Bowman							
3	I-15-SB	Sieben Int.	0-12	0.7	8.0		
4	I-15-SB	Gates of Mtn. Int.	0-10	2.3	5.3	1.5	6.6
Boulder Hill – Helena Transpo Sealate, T70 – 10							
5	I-15-SB	Abandoned BNRR	2-25	14.0	21.7	14.0	21.7
Three Forks – Manhattan SikaPronto 19							
6	I-90-EB	Darlington Ditch	0-10	5.6	5.6		
7	I-90-EB	County Rd. Sep.	0-2	0.3	1.3		
8	I-90-EB	Drainage Ditch	0-7	0.0	3.5		
9	I-90-WB	County Rd. Sep.	0-5	2.5	2.5		
10	I-90-WB	Drainage Ditch	1-3	1.0	2.5		
11	I-90-WB	Darlington Ditch	0-2	0.0	1.0	1.3	2.8
Bearmouth – Drummond American Concrete, Systems-Polytech Perma Seal							
12	I-90-WB	Clark Fork	1-5	2.0	3.3		
13	I-90-WB	Grade Sep.	1-25	2.3	9.7	10.9	14.1
14	I-90-EB	Clark Fork	0-44	28.3	29.3		
Missoula Dist. – Br. Rehab. Transpo Sealate, T – 70MX-30							
15	I-90	Rock Creek	0-2	0.5	1.0		
16	I-90	Clinton Overpass	0-0	0.0	0.0	0.25	0.5
St. Regis River Bridges Transpo, T 70 – X							
17	I-90-WB	St. Regis Riv.,	0-90	0.7	2.60		
18	I-90-WB	St. Regis Riv.,	0-9	1.0	4.7		
19	I-90-EB	St. Regis Riv.,	0-60	1.0	26.7		
20	I-90-EB	St. Regis Riv.,	1-12	1.0	7.0	1.0	17.7
St. Regis – Tarkio Transpo Sealate, T – 70NX-30							
21	I-90-EB	Clark Fork	1-30	4.0	17.3	4.0	17.3
East Missoula – Bonner Transpo Castek, T – 70MX-30							
22	I-90-WB	Blackfoot River	1-17	5.7	8.0		
23	I-90-WB	MRL Railroad	0-10	2.0	4.0		
24	I-90-WB	Clark Fork	0-12	3.3	8.0		
25	I-90-WB	Grade Separation	1-30	6.5	22.5		
26	I-90-WB	Clark Fork	25-55	30.0	40.0	8.1	14.2

TABLE 4 – MATERIAL SUMMARY BY MANUFACTURER

Manufacturer	Number of contracts	Number of bridges	Number of cores	Range of resin penetration (mm)	Avg. maximum penetration (mm)
American Concrete Systems	1	3	9	0-44	14 1
Harris Specialty Chemicals	2	4	12	0-90	14 5
Sika Corporation	1	6	14	0-10	2.8
Transpo	5	13	35	0-90	14 7

RESIN COMPARISON

Company Name	Product Name	Type of Resin	Bridge #	Core ID	Range of Crack Width (mm)		Avg. Crack Width (mm)	Range of Penetration (mm)	
Harris Specialty Chemicals	CrackSealer ULV	?	1	A	0.03	0.04	0.035	3	15
			1	B	0.33	0.33	0.330	2	3
			1	C	0.00	0.03	0.030	2	17
			2	A	0.3	0.5	0.400	90	90
			2	B	0.001	0.001	0.001	0	1
			2	C	0.07	0.07	0.070	2	9
Harris Specialty Chemicals/Watson Bowman	Wabo CrackSealer ULV	?	3	A	0.2	0.3	0.250	1	12
			3	B	0.08	0.1	0.090	1	12
			3	C	0.08	0.05	0.065	0	0
			4	A	0.1	0.1	0.100	0	1
			4	B	0.01	0.01	0.010	2	10
			4	C	0.08	0.08	0.080	0	5
Transpo	Sealate T70-10	Low elongation	5	A	0.01	0.01	0.010	2	20
			5	B	0.1	0.2	0.150	20	20
			5	C	0.004	0.004	0.004	20	25
Sika	SikaPronto 19	Low elongation	6	A	0.4	0.4	0.400	7	7
			6	B	0.01	0.05	0.030	0	0
			8	C	0.1	0.2	0.150	10	10
			7	A	1.2	1.2	1.200	1	2
			7	B	0.02	0.03	0.025	0	0
			7	C	0.04	0.04	0.040	0	2
			8	A	0.08	0.08	0.080	0	7
			8	B	0.15	0.15	0.150	0	0
			9	A	0.08	0.08	0.080	0	0
			9	B	0.1	0.5	0.300	5	5
			10	A	0.08	0.08	0.080	1	2
			10	B	0.04	0.04	0.040	2	3
			11	A	0.04	0.04	0.040	0	0
			11	B	0.4	0.4	0.400	0	2
American Concrete Systems	Polytech Perma Seal	?	12	A	0.1	0.2	0.150	2	2
			12	B	0.1	0.1	0.100	3	5
			12	C	0.01	0.01	0.010	1	3
			13	A	0.05	0.05	0.050	5	25
			13	B	0.15	0.15	0.150	1	2
			13	C	0.1	0.1	0.100	1	2
			14	A	0.02	0.03	0.025	44	44
			14	B	0.01	0.05	0.030	0	3
			14	C	0.01	0.01	0.010	41	41
Transpo	Sealate T70MX - 30	High elongation	15	A	0.1	0.1	0.100	1	2
			15	B	0.02	0.05	0.035	0	0
			16	A	0.04	0.04	0.040	0	0
			16	B	na / broken				
			21	A	0.2	0.2	0.200	2	30
			21	B	0.03	0.03	0.030	1	2
			21	C	0.2	0.3	0.250	10	20
Transpo	T70 -X	Low elongation	17	A	0.03	0.13	0.080	0	10
			17	B	0.01	0.03	0.020	2	90
			17	C	na / broken				
			17	D	0.005	0.05	0.028	1	2
			18	A	0.8	0.8	0.800	0	1
			18	B	na / broken				
			18	C	0.8	0.8	0.800	3	9
			19	A	0.2	0.2	0.200	1	20
			19	B	0.5	0.5	0.500	0	0
			19	C	0.02	0.03	0.025	2	60
			20	A	na / broken				
			20	B	0.5	0.5	0.500	1	2
Transpo	Castek T - 70MX-30	High elongation	22	A	0.02	0.03	0.025	1	2
			22	B	0.1	0.1	0.100	4	5
			22	C	0.7	1	0.850	12	17
			23	A	0.03	0.05	0.040	0	0
			23	B	0.1	0.3	0.200	1	2
			23	C	na / broken				
			24	A	0.4	0.4	0.400	0	12
			24	B	0.3	0.4	0.350	3	4
			24	C	0.2	0.4	0.300	7	8
			25	A	0.25	0.25	0.250	12	30
			25	B	0.35	0.4	0.375	1	15
			26	A	0.2	0.5	0.350	35	56
			26	B	0.2	0.2	0.200	25	25

Table 5 – Comparison of High and Low Elongation Resins

Figure 1 – Typical transverse deck cracking, underside (Br. No. 15)

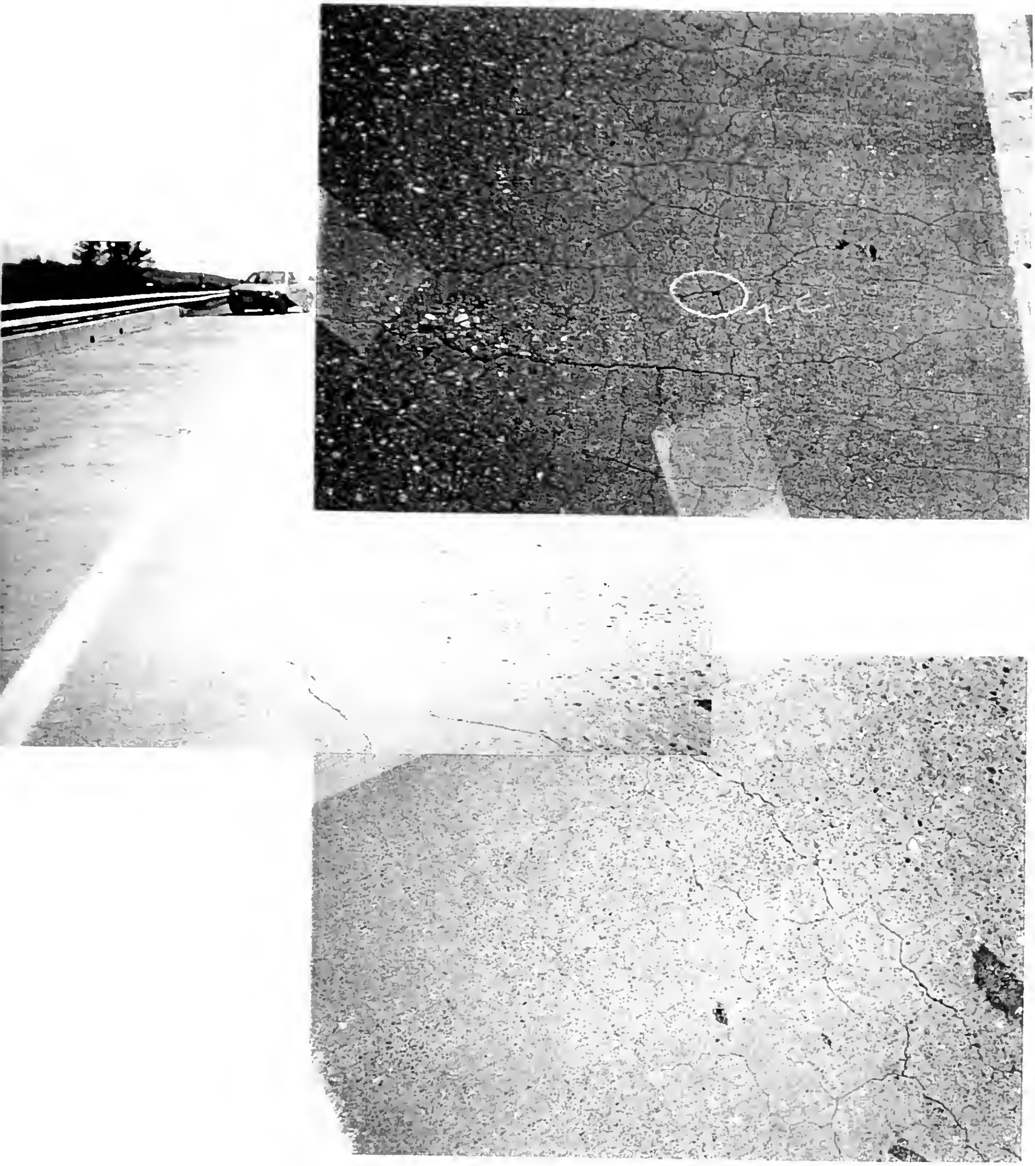

Figure 2 – Longitudinal and map cracking on Bridge Nos. 7 (top), 10 (middle), and 11 (bottom), Three Forks I-90 WB

Figure 3 – Deteriorated pcc patches on Bridge 9, Three Forks I-90 WB, Core location 9-A shown

Figure 4 – Transverse deck cracks highlighted after rain on Bridge No. 18, St. Regis I-90 WB, Core Location 18A

Figure 5 – Wetting surface of Bridge 13 (I-90 WB, Mile Post 143.651)

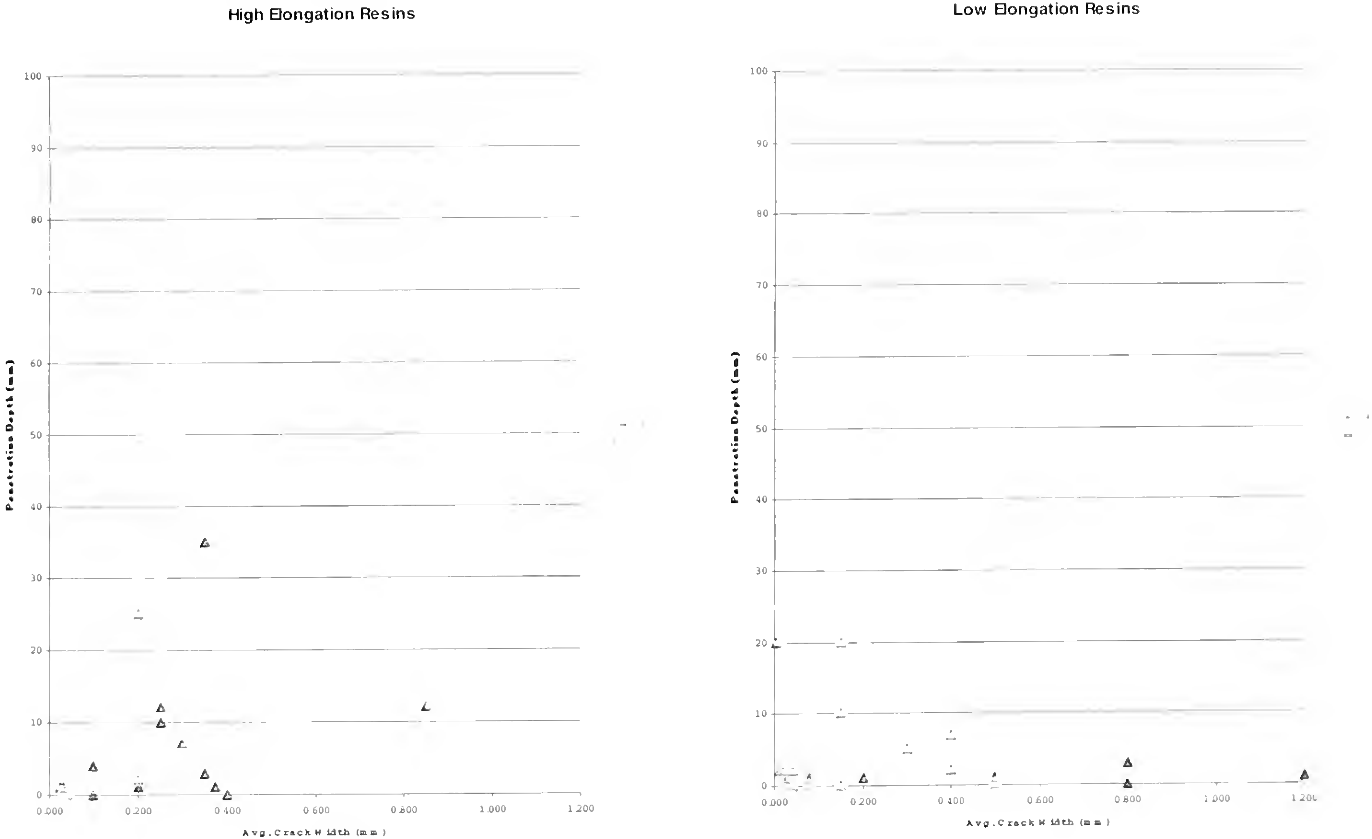

Figure 6 – Depth of penetration versus crack width for high and low elongation resins

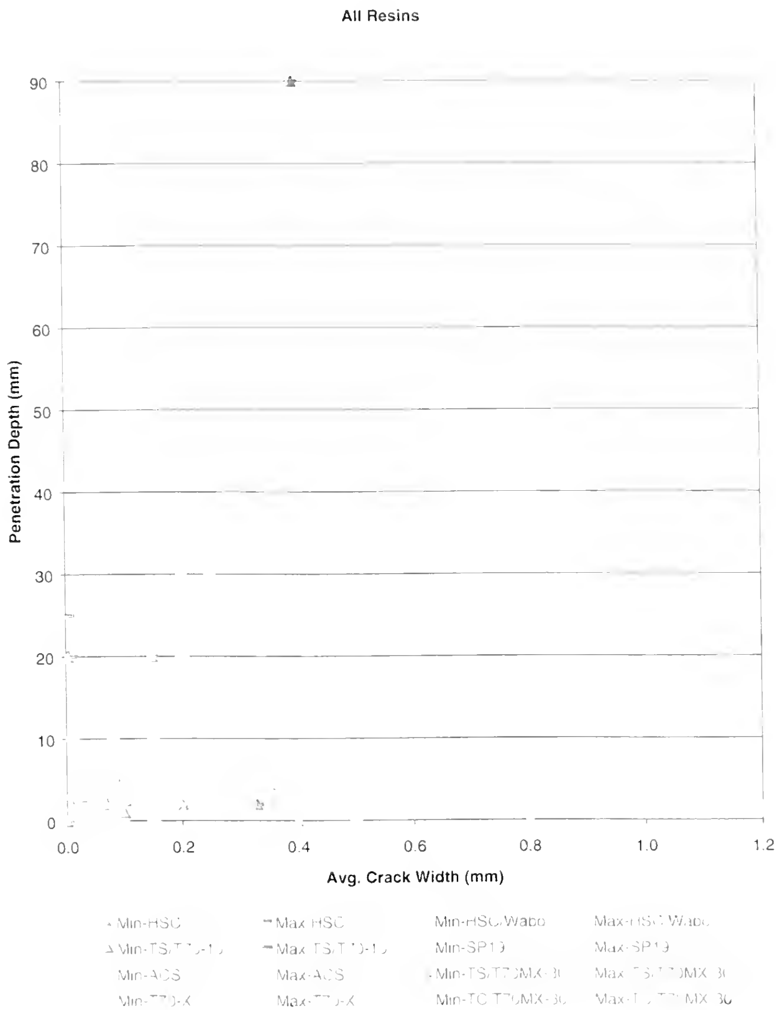

Figure 7 – Depth of penetration versus crack width for all cores

APPENDIX A

CORE LOG

CORE LOG

Core No.	Bridge	Date	Approximate		Crack type
			x (ft)	y (ft)	
1A	I-15 SB So. Cascade	8/16/99	4	11	Diagonal crack near abutment – sealed
1B	(mile point 254.942)		58	18	Transverse crack over bent – sealed
1C			90	13	Transverse crack near bent – surface resin cracked
2A	I-15 SB County Rd.	8/16/99	27	7	Shoulder-short diagonal crack, leaking – black #4 bar bot. clean
2B	(mile point 249.505)		60	17	Left wheelpath – typical longitudinal crack – pattern
2C			90	13	Right wheelpath – typical transverse crack over bent
3A	I-15 SB Sieben Int.	8/16/99	12	7	Shoulder transverse crack – efflorescence below
3B	(mile point 216.482)		54	15	℄/right wheelpath – typ. large transverse crack - 4-5' long
3C			72	13	Crack in patch/closure over joint/bent
4A	I-15 SB Gates of Mtn. Int.	8/16/99	17	14	Transverse crack – no resin on surface
4B	(mile point 209.108)		27	13	Transverse crack – resin on surface – Transverse bar bottom core clean except for minor corrosion or deformation
4C			80	12	Joint between patch/closure right wheelpath – open crack
5A	I-15 SB BNRR	8/16/99	90	15	Diagonal crack over bent
5B	(mile point 187.079)		144	5	Short transverse crack shoulder
5C			184	11	Medium pattern cracking
6A	I-90 EB Darlington Ditch	8/17/99	93	12	Large transverse crack
6B	(mile point 279.534)		70	16	Large transverse crack
6C			63	5	Transverse crack in shoulder
7A	I-90 EB County Rd.	8/17/99	100	10	Joint of pcc patch
7B	(mile point 280.361)		75	15	Typical large transverse crack
7C			33	11	Area of heavy map cracking
8A	I-90 EB Drainage Ditch	8/17/99	60	15	Transverse crack
8B	(mile point 280.1)		48	10	Transverse crack with map cracking
9A	I-90 WB County Rd. Sep.	8/17/99	87	14	Transverse crack in patch
9B	(mile point 280 361)		33	13	Transverse crack
10A	I-90 WB Drainage Ditch	8/17/99	9	11	Longitudinal crack in heavy map cracked area
10B	(mile point 280.1)		60	10	Area of heavy map cracking
11A	I-90 WB Darlington Ditch	8/17/99	42	11	Longitudinal map crack
11B	(mile point 279 534)		113	15	Transverse crack
12A	I-90 WB Clark Fork	8/18/99	52	13	Transverse crack
12B	(mile point 148.436)		102	10	Longitudinal crack
12C			215	10	Diagonal crack over pier
13A	I-90 WB Grade Separation	8/18/99	–	–	Intersection of cracks
13B	(mile point 143.651)		–	–	Transverse crack
13C			–	–	Intersection of cracks
14A	I-90 EB Clark Fork	8/18/99	60	6	Transverse crack - shoulder
14B	(mile point 148.436)		124	13	Transverse crack – lane
14C			210	8	Diagonal crack over pier
15A	I-90 Rock Creek Overpass	8/18/99	77	6	Transverse crack
15B	(mile point 126 039)		42	9	Transverse crack over pier
16A	I-90 Clinton Overpass	8/18/99	50	7	Transverse crack with resin on surface
16B	(mile point 120.993)		30	7	Transverse crack with efflorescence on underside
17A	I-90 WB St. Regis River	8/19/99	573	14	Transverse crack appears open
17B	County Rd.		162	11	Longitudinal crack with fine map cracking when wet
17C	(mile point 23.325)		105	12	Transverse crack, large, appears open
17D			300	18	Transverse cracks, appears sealed
18A	I-90 WB St. Regis River	8/19/99	110	10	Large transverse crack
18B	County Rd.		304	17	Longitudinal crack closer to pier with fine longitudinal crack
18C	(mile point 23.325)		396	14	Large transverse crack flooded due to bridge elevation

CORE LOG (cont'd)

Core No.	Bridge	Date	Approximate x (ft)	Approximate y (ft)	Crack type
19A	I-90 EB St. Regis River County Rd. (mile point 23.063)	8/19/99	153	18	Transverse crack with old core hole patch that cracked
19B			195	13	Transverse crack looks open in very flexible span of bridge
19C			243	14	Transverse crack smaller than A, which has old core hole that has not cracked
20A	I-90 EB St. Regis River County Rd. (mile point 23.325)	8/19/99	123	13	Construction joint (typical) with crack in pcc
20B			151	10	Transverse crack that appears filled
21A	I-90 EB Clark Fork (mile point 49.397) (main span)	8/19/99	120	6	Transverse crack in area of underside efflorescence
21B			58	5	Transverse crack, no leakage below, shorter crack (typ.) 5' long
21C			250	6	Transverse crack-sealed, in area to be repaired
22A	I-90 WB Blackfoot River (mile point 110.198)	8/20/99	120	12	Transverse crack in right wheelpath
22B			33	10	Transverse crack in right wheelpath
22C			77	8	Transverse crack in shoulder
23A	I-90 WB MRL RR (mile point 110.033)	8/20/99	139	16	Transverse crack
23B			145	17	Leaking crack below with efflorescence
23C			137	16	Transverse crack
24A	I-90 WB Clark Fork (mile point 109.409)	8/20/99	50	4	Transverse crack (short 4' long) – honeycombing 2½-3" deep
24B			113	5	Transverse crack – core broke at 3" during coring
24C			277	5	Transverse crack – full lane width
25A	I-90 WB Grade Separation (mile point 109.224)	8/20/99	50	12	Transverse crack – right wheelpath over pier
25B			105	12	Transverse crack – right wheelpath
26A	I-90 WB Clark Fork (mile point 108.276)	8/20/99	106	6	Transverse crack – right wheelpath (typical)
26B			109	5	Transverse crack – largest one visible on deck

APPENDIX B

BRIDGE SURVEY COMMENTS

BRIDGE SURVEY COMMENTS

Bridge 1	I-15 SB	So. Cascade [5]	MP 254.942	Applied 1998	Harris ULV
Precast I-beams. 3 span- simple					
Underside Southbound	Extensive deck cracking. Pattern cracks. Not much efflorescence. Some diagonal cracks near abutment. Overall clean. Only about 4 cracks with efflorescence near Span 1-2 (Newer structure?)				
Underside Northbound	Doesn't appear to have been treated. Underside mostly map cracking. Very few transverse cracks. Note: Northbound guard rail posts in poor condition – lack of cover. Black steel exposed and corroded. Damage may be ASR/FT.				
Top deck Southbound	Pattern cracks throughout travel lane. Some transverse but longitudinal cracks predominate. Looks like ASR. Resin has worn off in wheel paths.				
	Cores A-BC taken in worst areas of leaking and stains. No new cracks on surface since resin treatment.				

BRIDGE SURVEY COMMENTS

Bridge 2	I-15 SB		MP 249.505	Applied 1998	Harris ULV
Precast I-beams. 3 span- simple (5 girders)					
Underside	Span 1: Few random spots of efflorescence. Span 2-3: No visible leakage or efflorescence. Minimal light. pattern cracks , overall good condition.				

BRIDGE SURVEY COMMENTS

Bridge 3	I-15 SB	Sieben Int.	MP 216.482	Applied 1996	Harris Watson/Bowman
Precast girders 3 span- simple - continuous deck					
Deck southbound	Resin on surface is good. Some sand bonded at curb line. Many transverse cracks, some patches.				
Deck northbound	Still see resin on surface Concrete replacement over Span 1-2 and, 2-3 joints. New cracks in replacement.				
Underside southbound	Span 1: Pattern cracks, no efflorescence; diagonal crack near Abutment 1 with efflorescence (southwest corner). Transverse crack – efflorescence. Span 3: Transverse crack, 6-10 ft north abutment. Leaks over both bents. Diagonal crack Abutment 4 efflorescence (northeast corner).				
Underside northbound	The same leakage at both bents.				

BRIDGE SURVEY COMMENTS

Bridge 4	I-15 SB	Gates of Mtn. Int.	MP 209.108	Applied 1996	Harris Watson/Bowman
Precast pcc girders, simple span, continuous deck					
Underside southbound	Small diagonal crack at Abutment 1, (southwest) with efflorescence. Span 1: Very few cracks visible, efflorescence near joint between Span 1 and 2, maybe construction joint. Faint minor underside cracks - random. Underside very good, except at bents – cold joint.				
Underside northbound	Same as southbound.				
Top deck northbound	Closure/joint patches with crack - Joint detail not working. Same as No. 3 bridge.				
Top deck southbound deck	Some AC chip seal (brown) tracked on approach. Resin mostly worn off, except in deep pockets				

BRIDGE SURVEY COMMENTS

Bridge 5	I-15 SB	Abandoned BNRR	MP 187.079	Applied 1996	Transpo Sealate T70 - 10
Precast pcc girders - simple span – 5 spans - 5 girders					
Underside southbound	Minor pattern/random cracks. No through cracks showing efflorescence in Span 1, 2, or 3. Not a lot of deck cracking – some pattern cracks. Debris on bent cap 1 – through joint.				
Top deck southbound	Thin deck with **lots of steel**. Small bars – Core 5-A over bent.				

BRIDGE SURVEY COMMENTS

Bridge 6	I-90-EB	Darlington Ditch	MP 279.534	Applied 1993	Sika Pronto 19
Precast I-beams - - 3 span - simple supports					
Underside	Looks very good. No cracking				
Top deck	Extensive patching and transverse cracking. Map cracking medium to heavy in right wheelpath (WP); medium to light in left WP. Shoulder in good condition, with some transverse cracks and light map cracks. No evidence of HMWM on surface.				

BRIDGE SURVEY COMMENTS

Bridge 7	I-90-EB	County Rd. Sep.	MP 280.361	Applied 1993	Sika Pronto 19
Precast pcc girders –single span - continuous deck - 5 girders -					
Underside	Some pattern-random cracks. No efflorescence or leaking				
Top deck	Extensive map cracking in travel lane with predominant transverse cracking. Deck has many pcc patches placed prior to HMWM treatment.				

BRIDGE SURVEY COMMENTS

Bridge 8	I-90-EB	Drainage Ditch	MP 280.1	Applied 1993	Sika Pronto 19
Precast pcc girders – 2 span					
Top deck	Very similar to Bridge 7; pcc patches and map cracking in travel lane. Shoulder better with some transverse cracking. Main cracking is transverse. Cracks look much worse on surface than width suggests. Cracks tend to be very narrow within the concrete. Rebar in bottom of Core 8-B is not corroded				

BRIDGE SURVEY COMMENTS

Bridge 9	I-90-WB	County Rd. Sep.	MP 280.361	Applied 1993	Sika Pronto 19
Precast pcc girders – single span					
Underside	No leaking cracks or efflorescence.				
Top deck	Core 9A in patch showed patches only to top of top mat steel. Patch delaminated at bond line.				

BRIDGE SURVEY COMMENTS

Bridge 10	I-90-WB	Drainage Ditch	MP 280.1	Applied 1993	Sika Pronto 19
Precast pcc girders – 2 span					
Underside	Same as eastbound structure – Bridge 8.				
Top deck	Some pcc patches in travel way. Medium-heavy map cracking in right wheel path. Cracking tends to be more longitudinal than other bridges. Shoulder has light map cracking				

BRIDGE SURVEY COMMENTS

Bridge 11	I-90-WB	Darlington Ditch	MP 279.534	Applied 1993	Sika Pronto 19
Precast I beams – 3 span – simple supports					
Top deck	Many pcc patches. Most patches cracked. Map cracking in right wheelpath.				

BRIDGE SURVEY COMMENTS

Bridge 12	I-90-WB	Clark Fork	MP 148.436	Applied 1994	Am. Concrete Sys. Polytech Perma Seal
Precast I-beams - 4 span – 1, 4, short spans 10 girders wide - Spans 2, 3 long spans with large I-girders					
Underside	Span 1-4. Fine random cracking. Cracks and efflorescence under center median (transverse). No efflorescence or leaking cracks except in median/closure.				
Top deck	Resin present in holes, large cracks, and near curb. Longitudinal crack over girder No. 2, approx. 12 ft.				

BRIDGE SURVEY COMMENTS

Bridge 13	I-90-WB	Grade Separation	MP 143.651	Applied 1994	Am. Concrete Sys. Polytech Perma Seal
3 span pcc I-beams simple support – continuous deck 10 girders					
Underside	Typical random fine cracks on underside of deck. No leaking cracks or efflorescence Flooded surface with water. No leakage visible.				
Top deck	A few new cracks in deck. Black patches – Percol repairs looks good.				

BRIDGE SURVEY COMMENTS

Bridge 14	I-90-EB	Clark Fork River	MP 148.436	Applied 1994	Am. Concrete Sys. Polytech Perma Seal
Precast I-beams - 4 span – 1, 4, short span 10 girders wide - Span 2, 3 long spans-large I-girders					
Underside	No visible leaking cracks or efflorescence. Some fine random cracks but fewer than Three Forks Bridges.				
Top deck	Similar to Bridge 12 (WB) - Longitudinal crack intermittent along right wheelpath. Light map cracking along shoulder. More transverse cracks along shoulder. Not many cracks in travelway				

BRIDGE SURVEY COMMENTS

Bridge 15	I-90	Rock Creek Overpass	MP 126.039	Applied 1992	Transpo Sealate T-70MX-30I
pcc I beams 4 span 2 short 2 long spans 2 span continuous deck					
Underside	Lots of transverse cracks with lots of efflorescence. Doesn't look like it is sealed Sprinkled some water on Span 1 to look for leakage. No leakage after 15 min.				
Top deck	Transverse cracking worse in Span 1 near abutments. No map cracking				

BRIDGE SURVEY COMMENTS

Bridge 16	I-90	Clinton Overpass	MP 126.993	Applied 1992	Transpo Sealate T-70MX-30I
pcc I beams, 4 span					
Underside	Similar to Bridge 15 but less visible cracking underneath and much less efflorescence.				

BRIDGE SURVEY COMMENTS

Bridge 17	I-90-WB	St. Regis River Bridges	MP 23.325	Applied 1991	Transpo T 70 - X
4 span steel girder bridge					
Underside	Many transverse cracks with efflorescence or cracking is scattered with more cracks near mid span. Eastbound structure is similar. No active leaks after rain, paint peeling on steel girders				
Top deck	Resin preset in cracks and holes. Core 17A – right wheelpath large transverse crack, looks like it is open (Span 4). No map cracking noted on deck, except near Span 1-2 shoulder. Fine longitudinal crack between right wheelpath and EP stripe. Bridge approximately 660 ft long.				

BRIDGE SURVEY COMMENTS

Bridge 18	I-90-WB	St. Regis River Bridges	MP 23.063	Applied 1991	Transpo T 70 - X
3-span steel girder, continuous deck					
Underside	Transverse cracks with efflorescence Worse away from the abutments No active leakage after rain (but difficult to see). Cracks grouped in areas. Abutment and center span areas have no cracking				
Deck	Transverse cracking appears worse on shoulders of the two end spans. Twelve-foot shoulder, faint longitudinal cracking in right WP to EP stripe. Less transverse cracking over the piers and near the abutments. Good candidate bridge for transverse deck cracking due to large steel girders (flexible. The deck has about 47 obvious transverse cracks over its approximately 400-ft length. Flexible deck with vertical movement under live load. (same as 17).				

BRIDGE SURVEY COMMENTS

Bridge 19	I-90-EB	St. Regis River County Road	MP 23.063	Applied 1991	Transpo T 70 - X
3-span, steel girders, continuous deck					
Underside	Similar to Bridge 18.				
Deck	Resin still present on the shoulder. Some transverse cracks appear to be open. Some transverse cracks appear sealed with resin on surface, some not. Old core hole crack in core hole matches deck crack. Two other shorter cracks with old core holes – holes were not cracked. Deck is quite flexible. No map cracking.				

BRIDGE SURVEY COMMENTS

Bridge 20	I-90-EB	St. Regis River County Road	MP 23.325	Applied 1991	Transpo T 70 - X
4 span steel girder bridge					
Underside	Same as Bridge 17				
Deck	Cored through construction joint keyway. No map cracking. A few very fine longitudinal cracks near right wheel path (minor). Mostly transverse cracks similar to Bridge 17.				

BRIDGE SURVEY COMMENTS

Bridge 21	I-90-EB	Clark Fork River	MP 49.397	Applied 1994	Transpo Sealate T – 70MX-30
Multispan, steel beams and girders					
Underside westbound	Old steel girder/rivets. Lots of cracks with efflorescence and stalactites but dry after morning rain Main span less cracking than Span 1.				
Deck westbound	Lane passing was closed for pavement crack sealing. Deck has many transverse cracks and old patches. New spalls have occurred next to many of the old patches. Some rebar exposed Most patching previous to HMWM treatment. Resin is present in most cracks, but surface is cracked.				
Underside eastbound	Newer structure larger curved bolted steel beams. Much less through deck cracking on approach Span 1. Main spans – Two large steel girders outside with three small girders inside supported on cross-trusses. More through cracking and efflorescence in main span. Underside looks much better than top surface.				
Deck eastbound	Bridge has been recently surveyed and areas for repair marked. Extensive repair is indicated. Bridge deck has many spalls with exposed rebar – approximately ¾-in. cover. No. 1 lane looks fine. Candidate deck for corrosion inhibitor and overlay or CP overlay				

BRIDGE SURVEY COMMENTS

Bridge 22	I-90-WB	Blackfoot River	MP 110.198	Applied 1998	Transpo Castek T – 70MX-30
4 span – steel girders (2 main spans over river)					
Underside	Transverse cracks with efflorescence (typical). Cracks less severe in short end spans				
Deck	Recently treated, could not see cracks on surface. Heavy sand layer that is starting to wear in the wheelpaths. Cracks easier to see on west end of bridge. Deck is 8 in. thick The entire bridge is about 350 ft long – 9 ft shoulder, 12 ft lane.				

BRIDGE SURVEY COMMENTS

Bridge 23	I-90-WB	MRL Railroad	MP 110.033	Applied 1998	Transpo Castek T – 70MX-30
pcc beam end spans with steel beam center spans					
Underside	Span 2, 3, 4 steel. Spans 2 and 3 have steel beams and many leaking transverse cracks Span 4 (steel) and spans 5 and 6 (pcc) have only a few short leaking cracks				
Deck	Heavier sand than Bridge 23. Surface of deck covered with resin and sand Heavy coat. No map cracking 50-ft expansion joint (west) 300-ft joint 160-ft diagonal bent 354-ft end of bridge 237-ft expansion joint (east)				

BRIDGE SURVEY COMMENTS

Bridge 24	I-90-WB	Clark Fork and County Road	MP 109.409	Applied 1998	Transpo Castek T – 70MX-30
4 span steel girder					
Underside	Only a few small cracks visible with efflorescence.				
Deck	Has a heavy coat of resin and sand. Looks good. Typically, only transverse cracks that are raveled are visible through resin treatment. 2½-ft shoulder, 12-ft lane. Deck flexes under heavy truck loads. Core 24A has extensive honeycombing at 2½ in. Core 24B broke during coring at 3 in. 60-ft expansion joint (west) 192-ft diagonal bent 320-ft expansion joint (east) 370-ft diagonal bent 417-ft end of bridge – expansion joint Cracking: 0-30 ft near abutment diagonal cracks 30-60 ft some transverse cracks 60-90 ft some transverse cracks 90-105 ft no cracks 105-300 ft transverse cracks 300-417 ft very few cracks				

BRIDGE SURVEY COMMENTS

Bridge 25	I-90-WB	Grade Separation	MP 109.244	Applied 1998	Transpo Castek T – 70MX-30
pcc I beams, 3 span simple supported, continuous deck					
Underside	Looks good with minimal visible cracking.				
Deck	Has heavy layer of resin and sand. Looks good, 10½-ft shoulder, 12-ft travel lane.				

BRIDGE SURVEY COMMENTS

Bridge 26	I-90-WB	Clark Fork River	MP 108.276	Applied 1998	Transpo Castek T – 70MX-30
4 span steel girders (2 main center spans)					
Underside	Only an occasional through deck crack with efflorescence				
Deck	Has heavy coat of resin and sand hiding most cracks. Some transverse cracks visible in right wheelpath. No map cracking, visible through resin.				